

(12) **UK Patent Application** (19) **GB** (11) **2 020 735 A**

(21) Application No **7915969**
(22) Date of filing **9 May 1979**
(23) Claims filed **9 May 1979**
(30) Priority data
(31) **2820281**
(32) **10 May 1978**
(33) **Fed. Rep of Germany (DE)**
(43) Application published
21 Nov 1979

(51) **INT CL²**
F04B 45/08
(52) Domestic classification
F1A 1A1B 1A2 1A3 1B8B
1C3 2B 3C 4SX
(56) Documents cited
GB 1473688
GB1437552
GB 1432113
GB 1182908
GB 1141800
GB 650524

(58) Field of search
F1A
F1U

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(54) **Hose pump having a high dosing accuracy**

(57) A hose or peristaltic pump comprises a hose (1) resting against an abutment (2) and at least three plungers arranged and driven substantially perpendicularly to the length of the hose. Two plungers (4, 5) are operated as valves and the third plunger (3), arranged between the two valve plungers, is operated as a conveying plunger whereby a substantially accurate dosing is accomplished, especially if the plungers do not completely squeeze the hose together and also do not completely relieve the hose from the plunger action on the return stroke.

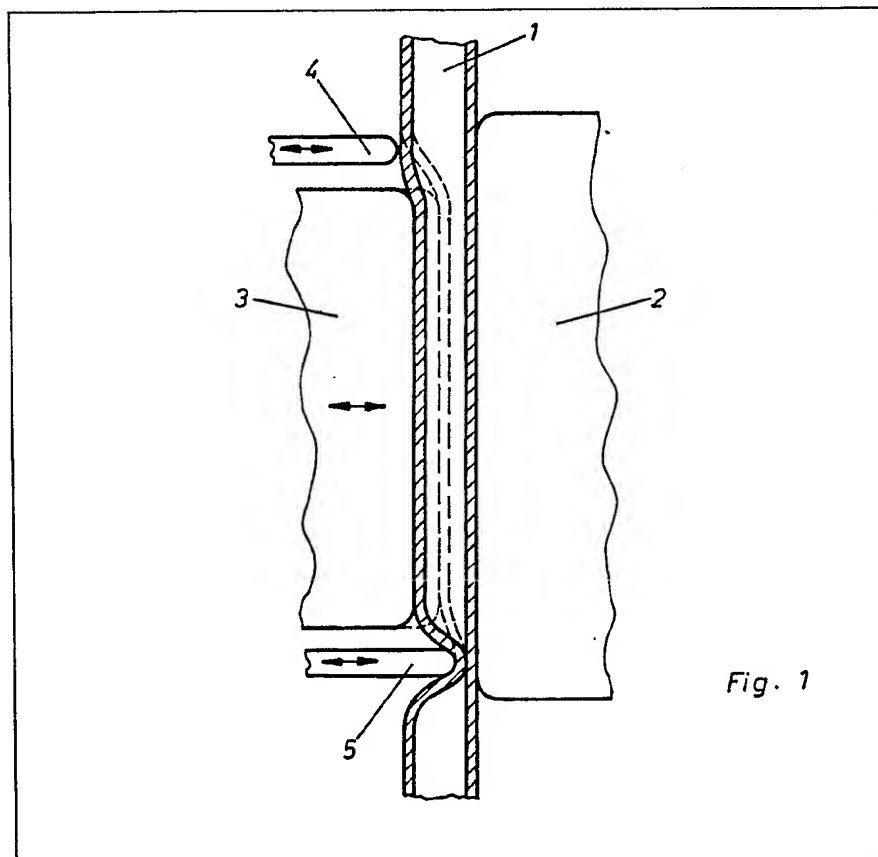


Fig. 1

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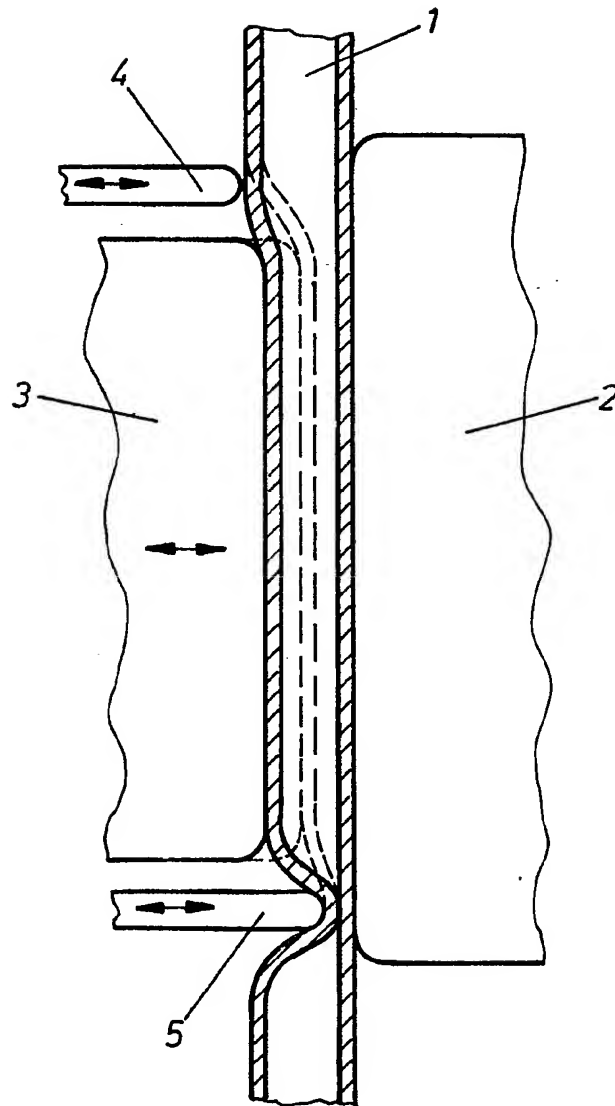


Fig. 1

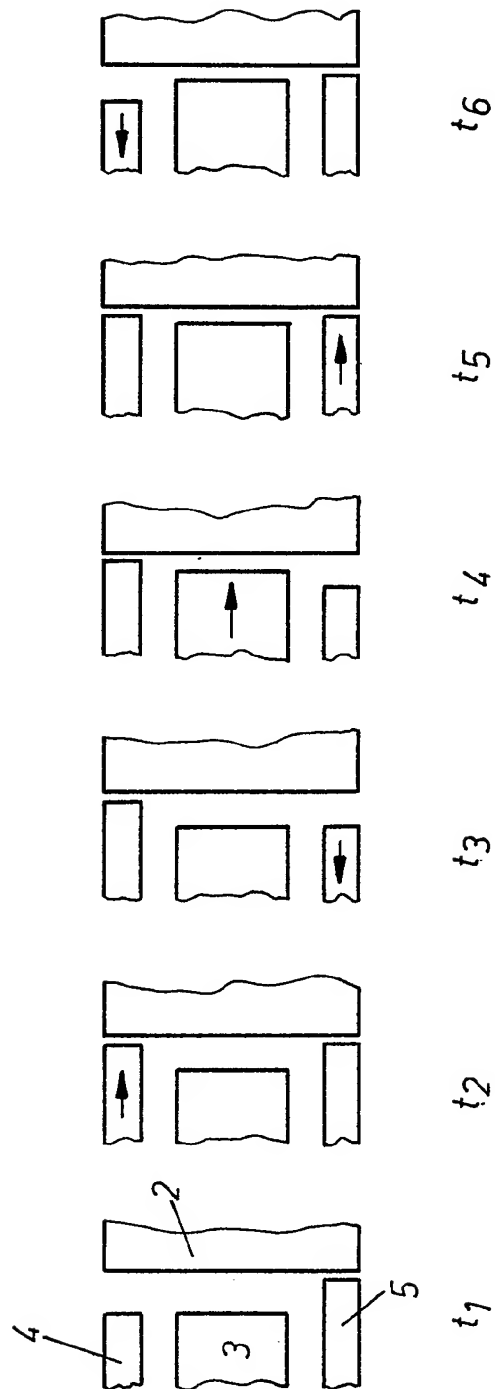
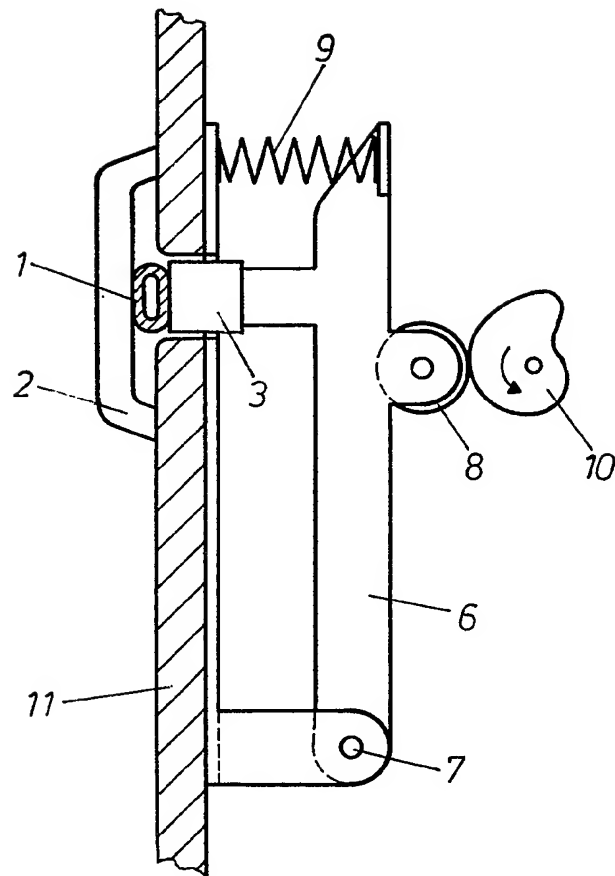


Fig. 2

*Fig. 3*

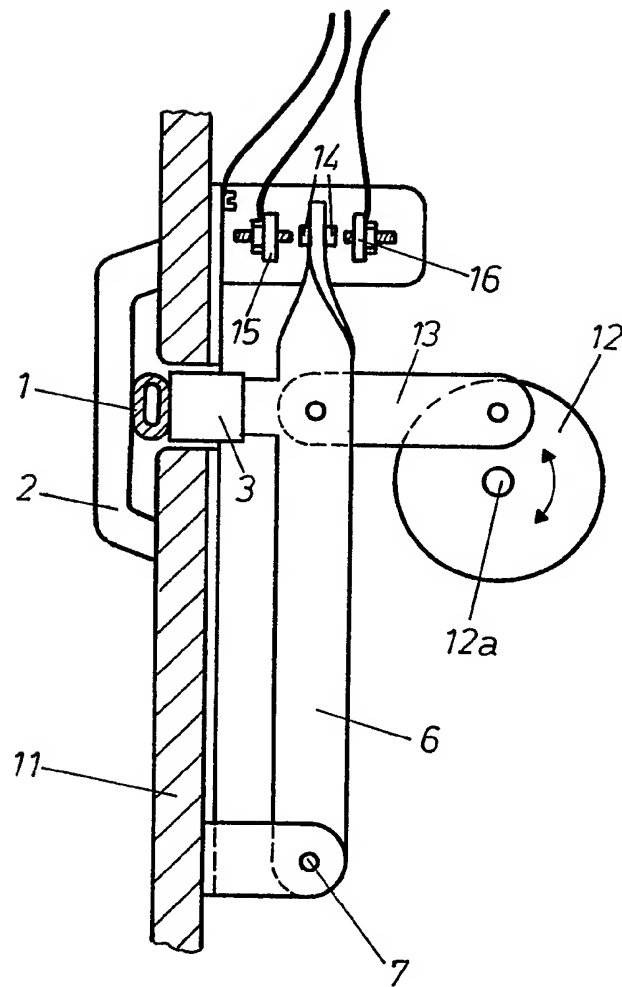
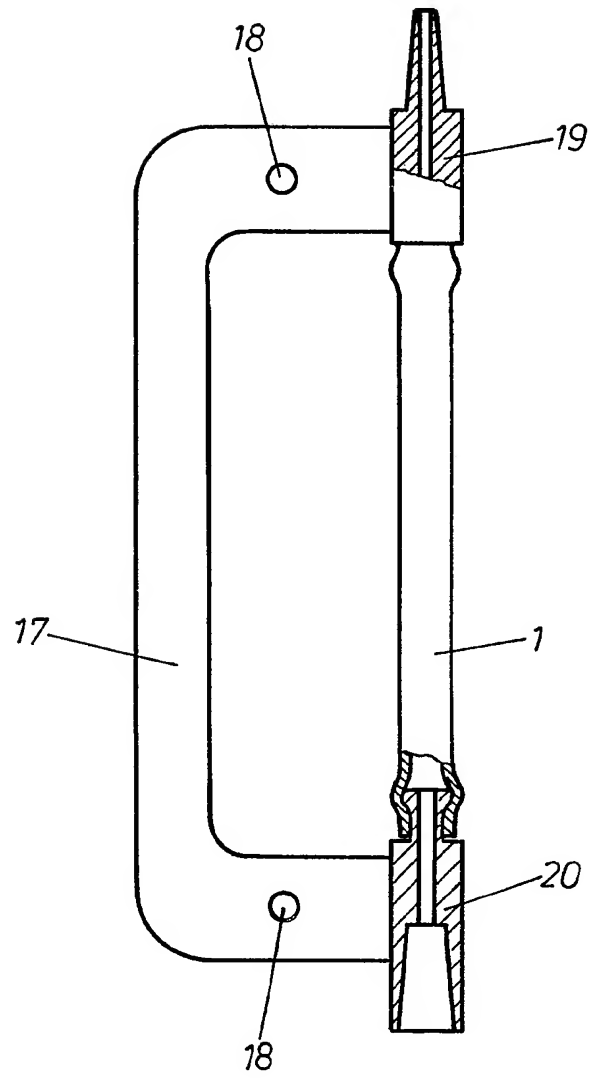


Fig. 4

*Fig. 5*

SPECIFICATION

Hose pump having a high dosing accuracy

5 The invention relates to a pump with a hose or a hollow body made of elastic material in the manner of a hose constituting a pump element. The invention especially aims at constructing a pump of this type having a high dosing accuracy.

10 Hose or peristaltic pumps are preferably used where it is absolutely necessary to avoid a contamination of the medium being conveyed, for example, in analysis techniques or in medical techniques. The essential advantage in this context is seen in that the medium being conveyed comes into contact exclusively with the hose which is easily exchangeable if necessary since it is a cheap one way article.

Hose pumps have become known heretofore in the form of finger pumps and roller pumps. Both 20 types of structures are peristaltic pumps wherein an external effect produces one or several bottle necks which travel along the hose thereby uniformly transporting the medium present in the hose. Normally the cross sectional area of the hose in the bottle neck is reduced to zero, that is, the hose is completely squeezed together by the external effect. Due to its elasticity, the hose substantially resumes, upstream and downstream of the bottle neck, its normal, circular cross section.

30 In the most common roller pump structure the hose is placed in a circular bend against the inner side of a stator also having a circular shape and forming an abutment. A rotor carries on its circumference rollers which roll along the hose resting against the stator. The axis of the rotor is supported in the center of the circular bend. The rollers pinch the hose together in the pressure point thereby transporting the medium to be conveyed in the direction of rotation of the rotor. In a simplified construction, referred to as the statorless roller pump, the outer abutment has been obviated. Instead, the hose placed on the rollers of the rotor is stretched to such an extent that the hose is completely pinched at the points of contact with the rollers even without pressing the hose against an abutment.

In the so-called finger pumps the hose is stretched out straight whereby one side of the hose wall rests along its entire length against a fixed abutment, 50 whereas on the opposite side of the hose there is arranged a larger number of plungers movable perpendicularly to the longitudinal axis of the hose in such a manner that by actuating any desired plunger the hose is pressed by the plunger against the abutment whereby the hose is squeezed together. A drive mechanism for the plungers causes the movement of all plungers in sequence in the feed advance direction whereby at least one plunger is always depressed in order to prevent a back flow of the medium being conveyed.

Hose pumps are suitable only to a limited extent for an exact dosing of the medium being conveyed. Controlling in this respect are, among others, the tolerances of the inner hose diameter and thus the 65 inner cross sectional area of the hose. Hoses that

have been manufactured by the extrusion process have inner diameter tolerances in the order of 2 - 3% even if the manufacturing is done very carefully. As a result, the minimal deviation of the cross sectional area and thus of the throughput quantity per unit of time is in the order of 4 - 6% in connection with hose pumps of conventional construction.

Another substantial reason for the imprecise dosing is due to the fact that the hose material fatigues 70 in the course of time as a result of which the hose does not return completely into its original shape after the load release due to a diminishing of its elasticity. This means a reduction in the inner cross sectional area and a diminishing of the feeding capacity. This fatiguing advances especially quickly when the hose is squeezed together with an excessive force which exceeds that measure of force necessary for the complete closing of the hose cross sectional area.

85 The inlet pressure on the suction side of the pump is further to be mentioned as an important influencing factor. A different degree of filling results as a function of the ratio between the inlet pressure and the elastic characteristics of the hose when different inlet pressure values are present thus causing a change in the throughput capacity. The mentioned fatiguing of the hose material also plays a substantial role in this context. This effect may appear very strongly especially when the inlet pressures are 95 negative.

Finally, it should be mentioned that positioning the pump hose in an unprecise manner is a possible influence of error in that the pump hose is, for example, twisted or fixed in the pump head with 100 different tensions effective along its axial length.

The invention has for its objective the avoiding of the mentioned disadvantages of conventional hose pump structures. The invention aims at constructing hose pumps which inherently have a higher dosing accuracy and which are capable to maintain such higher dosing accuracy substantially unchanged for a long operational life.

According to the invention there is provided a hose pump, comprising abutment means, hose means resting against said abutment means, at last three plunger means arranged for linear back and forth movement substantially perpendicularly relative to the length of said hose means, and drive means operatively connected to said plunger means 115 for actuating said three plunger means in a predetermined sequence relative to each other for reducing the inner hose cross-sectional area in hose zones located adjacent to each other in said predetermined sequence for conveying a medium through the hose means.

Further features are set forth in the following description and in the dependent claims.

The invention is described by way of example in the following text with reference to the figures of the 125 accompanying drawings.

Figure 1 shows a simplified illustration of the active part of a pump for elucidating the operational principle;

Figure 2 shows a schematic illustration of the movement sequence for the active part of a pump;

Figure 3 shows a first embodiment of the drive mechanism;

Figure 4 shows a second embodiment of the drive mechanism; and

- 5 Figure 5 shows a pump hose with a holding device constituting a preassembled unit.

Reference number 1 designates the pump hose in Figure 1 which rests on one side against a fixed abutment bearing 2. Three movable plungers are arranged on the other side comprising one piston plunger 3 and two valve plungers 4 and 5.

These plungers are actuated by a respective mechanism in the same manner as the pistons and valves of a piston pump. The movement sequence is illustrated in Figure 2 for completeness sake. At the point of time t_1 the outlet valve plunger 5 is closed, the inlet valve plunger 4 is opened and the piston plunger 3 is in its extreme position in which it opens the hose cross section to the maximum extent. Thus, in this starting condition the hose is filled with the medium to be conveyed which was sucked in from above. At the point of time t_2 the inlet valve plunger has again pinched the hose at the inlet side. At the point of time t_3 the outlet valve plunger is opened for preparing the subsequent squeezing of the content of the hose by means of the piston plunger. This squeezing is already completed at the point of time t_4 . The outlet valve plunger has again squeezed tight the hose at the outlet at the point of time t_5 . Thereafter, at the point of time t_6 the inlet valve plunger again opens the inlet. Thereafter the same operating status takes effect as at the point of time t_1 and so forth.

In order to minimize the influence of the inlet pressure on the filling degree of the hose, the invention provides that the piston plunger does not completely release the hose in the position in which the piston plunger is spaced away from the abutment bearing. Rather, in this position the piston plunger still squeezes the hose to a determined extent, for example, in the order of $1/3$ of the hose's outer diameter. Thus, even in this extreme position the hose is still resting against the abutment bearing and against the piston plunger with a certain bias, whereby the hose has a very small tendency to change its inner cross sectional area under the influence of differing pressure values.

This feature is even effective when the hose material fatigues due to the load to which the pump is subjected. Such fatiguing would otherwise make itself noticeable as a flattening of the hose cross section.

It may further be provided that the piston plunger does not completely compress the hose. Rather, in the position of the piston plunger in which the latter has the least spacing from the abutment bearing, this spacing may still be more than twice the wall thickness of the hose. Thus, the loading of the hose material is substantially reduced.

60 The mentioned features in which the maximally possible stroke of the piston plunger is not utilized, further reduces the influence of the tolerances of the hose's inner diameter on the throughput quantity of each piston stroke. The tolerance of the inner hose diameter affects the stroke volume with twice its

percentage value during the maximum stroke due to the square dependency of the hose cross section from the hose diameter. In this connection the maximum stroke means the complete release of the hose on the one hand and its complete compression on the other hand. However, in the other extreme, if the hose is maintained in a substantially flattened condition and if it is subjected to a respectively small stroke, there is only a linear dependency of the stroke volume from the original hose diameter so that the percentage tolerance of the hose inner diameter is effective on the stroke volume only in a linear manner. If operating conditions are selected which fall in between the two mentioned extreme operating conditions, the percentage tolerance of the inner hose diameter is correspondingly effective on the stroke volume and thus in the throughput capacity of the pump with a factor falling between 1 and 2.

85 For example, if a hose is used having an inner diameter of $10\text{mm} \pm 0.2\text{mm}$ tolerance that is with a diameter tolerance of 2%, the tolerance of the stroke volume is about 4% for the maximum stroke of 10mm. If, however, the same hose is used in a pump of the type described with a reduced stroke and a variation of the inner clearance in the range of 1 - 6 mm, the tolerance of the stroke volume is only about 3%.

Thus, a higher precision of the feed capacity is inherently achieved. In addition, this higher precision is maintained over very long operational periods and substantially independent of variations of the inlet pressure due to the above described characteristic features.

100 An example for a possible embodiment of the drive mechanism for the piston plunger is schematically illustrated in Figure 3. The piston plunger 3 is secured to a lever 6 one end of which is movably supported in a journal 7. The lever carries a rotatably supported roller 8. The pressure spring 9 presses the lever with the roller 8 against a cam 10 which is rotated by a motor and gear drive not shown. In accordance with the contour of the cam 10 the piston plunger 3 performs a quasi linear back and forth movement due to the large length of the lever 6 thereby compressing the pump hose 1 accordingly. The pump hose rests with its other side against the abutment bearing 2. This abutment bearing is, for example, constructed as a flap which may be locked in position on the front plate 11.

For certain purposes, for example, in connection with infusion pumps it is desirable to achieve a liquid conveyance which is as uniform as possible. For this purpose it is possible to construct the described arrangement as a push-pull pump system comprising two pump hoses whereby respectively one hose is in the suction phase of operation while the other hose is in the expulsion phase. By respectively shaping the cam 10 as shown in the single stroke embodiment of Figure 3, it is assured that the suction phase is very short relative to the expulsion phase so that a uniform liquid discharge takes place with brief interruptions.

The drive for the valve plungers may be constructed in the same manner as the drive for the

piston plunger. A modification may comprise the feature that the valves are closed by a spring force and opened by the cam drive. For this purpose the pressure spring 9 is to be replaced by a tension spring and the cam drive is to be arranged on the opposite side of the lever 6. Other types of drive mechanisms are also suitable which produce a substantially linear motion and which especially assure for the drive of the piston plunger a precisely defined stroke.

Figure 4 shows an embodiment of a drive mechanism for the piston plunger which is especially suitable for infusion pumps. The back and forth movement of the lever 6 is caused in this instance by the crank disk 12 which is rotated in alternately opposite directions. The crank disk 12 is connected by the push rod 13 to the lever 6. The drive of the crank disk 12 is accomplished by means of an electric gear drive motor having a reversible rotational direction whereby the control of the reversing of the rotational direction is triggered by the movement of the lever 6 itself. For this purpose the lever carries contact pieces 14 which come into contact members 15 and 16 in the extreme positions of the lever. The contacts are operatively connected to a switching mechanism through the connected conductors which switching mechanism causes in a known manner the reversal of the rotational direction. The arrangement shown in Figure 4 has the advantage that the stroke may be varied by a respective adjustment of the contacts 15 and 16. The switching signals may in addition be used for an electrical function control as well as for an electrical counting of the pump stroke. This arrangement further provides the possibility to use different rotational speeds for both rotational directions of the motor to thereby vary the time ration between the suction phase and the expulsion phase of the pump. This feature is advantageous for a very large variation range of the throughput capacity because thus it is possible to keep the speed of movement within controllable limits even at the highest adjustable feed capacity.

The described operational principle of the pump provides the possibility to measure and monitor the produced pressure with regard to its size, for example, with reference to the requirement that a determined pressure range may not be exceeded.

This feature is among others of interest in order to recognize a flow impedance on the flow off side to thereby take preventive steps relative to trouble that could be caused thereby. For this purpose the fact is utilized that a large proportion of the drive power of the piston plunger is actually converted into pumping work, whereby the force of the piston less the force necessary for the deformation of the hose itself is proportional to the produced pressure in the described working principle. This is contrary to other types of hose pumps in which a high undefined friction and flexing work is used up. If a d.c. motor is used for the drive, for example, having a high efficiency and if in addition small frictional losses are assured in the driving mechanism, then the current flowing into the motor during the expulsion phase is an indirect measure for the pressure present at the

output of the pump. Thus, according to a further embodiment of the teaching of the invention it is provided that the current taken up by the motor is measured respectively in a determined time range of the expulsion phase and to compare the measured current with a given rated value. This may be accomplished for example, in that the voltage drop across a resistor in the current circuit of the motor is supplied to one input of a voltage comparator, the other input of which is connected to a predetermined voltage value.

The output of the comparator is supplied to an AND-gate. An addressing signal is present at the second input of the AND-gate. The addressing signal is synchronized with the drive in order to limit the addressing to a determined section of the expulsion phase. At the output of the AND-gate there is thus available a signal which provides information regarding the exceeding of a determined pressure. This signal may, for example, be used for triggering a warning signal or for other functions.

If the pump is used as an infusion pump it is possible that the pressure monitoring as described may serve for preventing dangerous instances of a paravascular infusion. Such instances may occur when the infusion cannula displaces itself out of the blood vessel into the surrounding tissue so that the liquid exits into the tissue which, however, takes place against an increased flow resistance. A suitable arrangement of the system for this type of use may reside in that the respective current measured in a determined time period of the expulsion phase is indicated on a display instrument which is provided with an adjustable maximum limit value indicator and which is connected with an apparatus for triggering an alarm signal in order to show when the measured value exceeds the limit value.

Another suitable embodiment may reside in that the comparing value is made dependent from the adjustment of the pump speed in the sense that the comparing value is also increased when the pump speed is adjusted to a higher value. The exceeding of the comparing value causes an alarm signal. In this way the influence of the flow resistance in the discharge conduit especially the flow resistance in the infusion cannula is taken into consideration ahead of time with a certain approximation.

In order to avoid errors resulting from a non-precise insertion of the pump hose and in order to additionally simplify the handling, it is suggested according to the invention to provide the pump hose with a holding device which, for example, according to Figure 4 comprises a holding bail 17 provided with fitting bores 18 or similar form elements. These form elements are brought into operative contact with corresponding counter elements, for example, setting pins secured to the stationary part of the pump in order to bring the pump hose into a precisely defined position relative to the drive mechanism. This facilitates exchanging the pump hose which must be replaced relatively frequently where the pump is used for medical purposes. The holding device which forms with the pump hose a preassembled unit makes sure that the pump hose may not be twisted and that it is stretched along a straight line

between the connecting pieces with a precisely defined tension. The embodiment of the holding bail 17 shown in Figure 4 with the fitting bores 18 merely represents one example embodiment. The construction of the end pieces 19 and 20 and the manner of securing the pump hose 1 to the holding device may be correspondingly modified in accordance with the requirements.

10 CLAIMS

1. A hose pump, comprising abutment means, hose means resting against said abutment means, at least three plunger means arranged for linear back and forth movement substantially perpendicularly relative to the length of said hose means, and drive means operatively connected to said plunger means for actuating said three plunger means in a predetermined sequence relative to each other for reducing the inner hose cross-sectional area in hose zones located adjacent to each other in said predetermined sequence for conveying a medium through the hose means.

2. The pump of claim 1, wherein said at least three plunger means are arranged adjacent to each other to form a cooperating group of which two plunger means act as valves, and wherein the third plunger means is located intermediate the two valve plunger means and acts as a conveying plunger means.

3. The pump of claim 2, wherein said conveying plunger means comprise a plunger having a given width in the longitudinal direction of the hose means, said valve plunger means each having a valve plunger with a respective width in the longitudinal hose direction, said given width being larger than the respective width of the two valve plungers located upstream and downstream of said conveying plunger.

4. The pump of claim 1, 2, or 3, wherein said plunger means load said hose means in the rest position of the plunger means to a predetermined extent.

5. The pump of any one of claims 1 to 4, wherein said plunger means compress said hose means in the working position of the plunger means to a predetermined extent without completely compressing the hose means.

6. The pump of any one of claims 1 to 5, wherein said drive means comprise cam shaft means, cam means secured in staggered relationship on said cam shaft means for operating said plunger means in a predetermined sequence.

7. The pump of any one of claims 1 to 5, wherein said drive means comprise crank drive means, operatively connecting said crank drive means to said plunger means for operating said plunger means in a predetermined sequence.

8. The pump of any one of claims 1 to 7, wherein said drive means are operatively connected to said plunger means for accelerating said plunger means during their hose pinching stroke with a given acceleration and for accelerating said plunger means during their return stroke with an acceleration which differs from said given acceleration.

9. The pump of any one of claims 1 to 8, wherein said plunger means perform stroke movements which differ from each other.

10. The pump of any one of claims 1 to 9, further comprising electrical circuit means for energizing said drive means in opposite directions, and contact means operatively interposed in said electrical circuit means for reversing the drive direction in response to the movement of said drive means.

11. The pump of any one of claims 1 to 10, further comprising handle means, means operatively securing said handle means to said hose means, and locking means operatively arranged for properly positioning the hose means relative to said abutment means in a fixed manner.

12. A hose pump constructed and arranged substantially as described with reference to Figures 1 to 5 of the accompanying drawings.

Printed for Her Majesty's Stationery Office by Croydon Printing Company Limited, Croydon Surrey, 1979.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY,
from which copies may be obtained.